

Annex F

Methodology for Estimating Methane Emissions from Petroleum Systems

The methodology for estimating methane emissions from petroleum systems is being updated. EPA anticipates that current methodology understates emissions, and that the new methodology will be incorporated into future inventories. The following steps, however, were used to estimate methane emissions from petroleum systems for this report.

Step 1: Production Field Operations

The American Petroleum Institute (API) publishes active oil well data in reports such as the *API Basic Petroleum Data Book*. To estimate activity data, the percentage of oil wells that were not associated with natural gas production (an average of 56.4 percent from 1990 through 1997) was multiplied by the total number of wells in the United States. This number was then multiplied by per well emission factors for fugitive emissions and routine maintenance from Tilkicioglu & Winters (1989). Table F-1 displays the activity data, emission factors, and emissions estimates used.

Step 2: Crude Oil Storage

Methane emissions from storage were calculated as a function of annual U.S. crude stocks less strategic petroleum stocks for each year, obtained from annual editions of the *Petroleum Supply Annual published by the* Energy Information Administration (EIA 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998). These stocks were multiplied by emission factors from Tilkicioglu & Winters (1989) to estimate emissions. Table F-2 displays the activity data, emission factors, and emissions estimates used.

Step 3: Refining

Methane emissions from refinery operations were based on U.S. refinery working storage capacity. The EIA reports this data every two years. The data was last reported in 1997 for the 1996 estimates. Consequently, 1997 data for total U.S. refinery working storage capacity were not available. These estimates were derived using the average of the percent difference each year from 1990 through 1996 (EIA 1990, 1991, 1992, 1993, 1994, 1995, 1997). This capacity was multiplied by an emission factor from Tilkicioglu & Winters (1989) to estimate emissions. Table F-3 provides the activity data, emission factors, and emissions estimates used.

Step 4: Tanker Operations

Methane emissions from the transportation of petroleum on marine vessels were estimated using activity data on crude oil imports, U.S. crude oil production, Alaskan crude oil production, and Alaskan refinery crude oil capacity. All activity data, excluding the Alaskan refinery crude oil capacity estimates, were taken from annual editions of the *Petroleum Supply Annual* (EIA 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998). The capacity estimates are reported every two years but were not reported for 1997. The data were derived using the average of the percent difference in Alaskan refinery crude oil capacity each year from 1990 through 1996 (EIA 1990, 1991, 1992, 1993, 1994, 1995, 1997).

Tilkicioglu & Winters (1989) identified three sources of emissions in the transportation of petroleum. These are emissions from loading Alaskan crude oil onto tankers, emissions from crude oil transfers to terminals, and ballast emissions.

Step 4.1: Loading Alaskan Crude Oil onto Tankers

The net amount of crude oil transported by tankers was determined by subtracting Alaskan refinery capacity from Alaskan crude oil production. This net amount was multiplied by an emission factor from Tilkicioglu & Winters (1989) to estimate emissions. The activity data and emissions estimates are shown in Table F-4.

Step 4.2: Crude Oil Transfers to Terminals

Methane emissions from crude oil transfers were taken from the total domestic crude oil transferred to terminals. This amount was assumed to be 10 percent of total domestic crude oil production less Alaskan crude oil production. To estimate emissions, this transferred amount was multiplied by an emission factor from Tilkicioglu & Winters (1989). The activity data and emissions estimates are shown in Table F-5.

Step 4.3: Ballast Emissions

Ballast emissions are emitted from crude oil transported on marine vessels. This amount was calculated from the sum of Alaskan crude oil on tankers, the amount of crude oil transferred to terminals, and all crude oil imports less Canadian imports. Ballast volume was assumed to be 17 percent of this sum (Tilkicioglu & Winters 1989). This amount was then multiplied by an emission factor to estimate emissions. The activity data and emissions estimates are shown in Table F-6.

Total emissions from tanker operations are shown in Table F-7.

Step 5: Venting and Flaring

Methane emissions from venting and flaring were based on 1990 emissions estimates from EPA (1993) and were held constant through 1997 due to the lack of data available to assess the change in emissions.

Table F-1: CH₄ Emissions from Petroleum Production Field Operations

Variable	Units	1990	1991	1992	1993	1994	1995	1996	1997
Total Oil Wells		587,762	610,204	594,189	583,879	581,657	574,483	574,419	573,504
% Not Assoc. w/ Natural Gas	%	55.6%	56.4%	56.7%	56.7%	56.6%	56.7%	56.5%	56.5%
Oil Wells in Analysis		326,982	343,873	336,749	330,843	329,366	325,451	324,362	323,883
Emission Factors									
Fugitive	kg/well/yr	72							
Routine Maintenance	kg/well/yr	0.15							
Emissions									
Fugitive	mill kg/yr	23.5	24.8	24.3	23.9	23.7	23.4	23.4	23.3
Routine Maintenance	mill kg/yr	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05

Table F-2: CH₄ Emissions from Petroleum Storage

Variable	Units	1990	1991	1992	1993	1994	1995	1996	1997
Total Crude Stocks	1000 barrels/yr	908,387	893,102	892,864	922,465	928,915	894,968	849,669	868,119
Strategic Petroleum Stocks	1000 barrels/yr	585,692	568,508	574,724	587,080	591,670	591,640	566,000	563,429
Crude Oil Storage	1000 barrels/yr	322,695	324,594	318,140	335,385	337,245	303,328	283,669	304,609
Emission Factors									
Breathing	kg CH ₄ /brl/yr	0.002612							
Working	kg CH ₄ /brl/yr	0.002912							
Fugitive	kg CH ₄ /brl/yr	4.99x10 ⁻⁵							
Emissions									
Breathing	kg/yr	842,892	847,853	830,994	876,039	880,897	792,305	740,955	795,862
Working	kg/yr	939,602	945,131	926,339	976,552	981,968	883,210	825,969	887,176
Fugitive	kg/yr	16,118	16,213	15,891	16,752	16,845	15,151	14,169	15,219
Total Emissions	mill. kg/yr	1.80	1.81	1.77	1.87	1.88	1.69	1.58	1.70

Table F-3: CH₄ Emissions from Petroleum Refining

Variable (Jan 1)	Units	1990	1991	1992	1993	1994	1995	1996	1997
Refinery Storage Capacity	1000 barrels/yr	174,490	171,366	167,736	170,823	164,364	161,305	158,435	155,929
Storage Emission Factor	Mg CH ₄ /bbl/yr	5.9 x 10 ⁻⁵							
Emissions	mill. kg/yr	10.29	10.10	9.89	10.07	9.69	9.51	9.34	9.19

Table F-4: CH₄ Emissions from Petroleum Transportation: Loading Alaskan Crude Oil onto Tankers (Barrels/day)*

Variable	1990	1991	1992	1993	1994	1995	1996	1997
Alaskan Crude	1,773,452	1,798,216	1,718,690	1,582,175	1,558,762	1,484,000	1,393,000	1,296,000
Alaskan Refinery Crude	229,850	239,540	222,500	256,300	261,000	275,152	283,350	293,989
Net Tankered	1,543,602	1,558,676	1,496,190	1,325,875	1,297,762	1,208,848	1,109,650	1,002,011
Conversion Factor (gal oil/ barrel oil)	42							
Emission factor (lbs/gallon)	0.001							
Emissions @ Loading AK (lbs/day)	64,831	65,464	62,840	55,687	54,506	50,772	46,605	42,084
Methane Content of Gas (%)	20.80%							
Emissions @ Loading AK (mill kg/yr)	2.23	2.26	2.17	1.92	1.88	1.75	1.61	1.45

* Unless otherwise noted

Table F-5: CH₄ Emissions from Petroleum Transportation: Crude Oil Transfers to Terminals (Barrels/day)*

Variable	1990	1991	1992	1993	1994	1995	1996	1997
US Crude Production	7,355,307	7,416,545	7,190,773	6,846,666	6,661,578	6,560,000	6,465,000	6,452,000
AK Crude Production	1,773,452	1,798,216	1,718,690	1,582,175	1,558,762	1,484,000	1,393,000	1,296,000
US Crude - AK Crude	5,581,855	5,618,329	5,472,082	5,264,490	5,102,816	5,076,000	5,072,000	5,156,000
10% transported to terminals	558,185	561,833	547,208	526,449	510,282	507,600	507,200	515,600
Conversion Factor (gal oil/ barrel oil)	42							
Emission factor (lbs/gallon)	0.001							
Emissions from Transfers (lbs/day)	23,444	23,597	22,983	22,111	21,432	21,319	21,302	21,655
Methane Content of Gas (%)	20.80%							
Emissions from Transfers (mill kg/yr)	0.81	0.81	0.79	0.76	0.74	0.73	0.73	0.75

* Unless otherwise noted

Table F-6: CH₄ Emissions from Petroleum Transportation: Ballast Emissions (Barrels/day)*

Variable	1990	1991	1992	1993	1994	1995	1996	1997
Crude Imports (less Canadian)	5,251,701	5,038,786	5,300,616	5,886,921	6,079,773	6,125,482	6,909,429	7,787,604
Alaskan Crude (Net Tankered)	1,543,602	1,558,676	1,496,190	1,325,875	1,297,762	1,208,848	1,109,650	1,002,011
10% Crude Prod. Transported to terminals	558,185	561,833	547,208	526,449	510,282	507,600	507,200	515,600
Conversion Factor (gal oil/ barrel oil)	42							
Emission factor (lbs/1000 gallons)	1.4							
Crude Oil Unloaded	7,353,489	7,159,296	7,344,015	7,739,245	7,887,816	7,841,930	8,526,279	9,305,215
Ballast Volume (17% of Crude Unloaded)	1,250,093	1,217,080	1,248,483	1,315,672	1,340,929	1,333,128	1,449,467	1,581,887
Ballast Emissions (lbs/day)	73,505	71,564	73,411	77,361	78,847	78,388	85,229	93,015
Methane Content of Gas (%)	20.80%							
Ballast Emissions (mill kg/yr)	2.53	2.47	2.53	2.67	2.72	2.70	2.94	3.20

* Unless otherwise noted

Table F-7: Total CH₄ Emissions from Petroleum Transportation

Year	Million kg/yr
1990	5.6
1991	5.5
1992	5.5
1993	5.4
1994	5.3
1995	5.2
1996	5.3
1997	5.4